Space Weather Technical Forecast

Issued on Thursday, 14 September 2023 at 13:12 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Daily Chance of R1. Slight Chance G1 throughout, gradually falling with time.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity rose to Moderate in the last 24 hours, with a large, long-period M1.4 flare from an energetic filament eruption in the northwest quadrant, immediately northeast of the largest and most complex sunspot region on the disc, AR3423. This event has been confirmed as becoming interplanetary in STEREO A coronagraph imagery, however there is not yet enough for an accurate analysis. Very provisionally, there is a chance of at least glancing incidence of a CME from such a location.

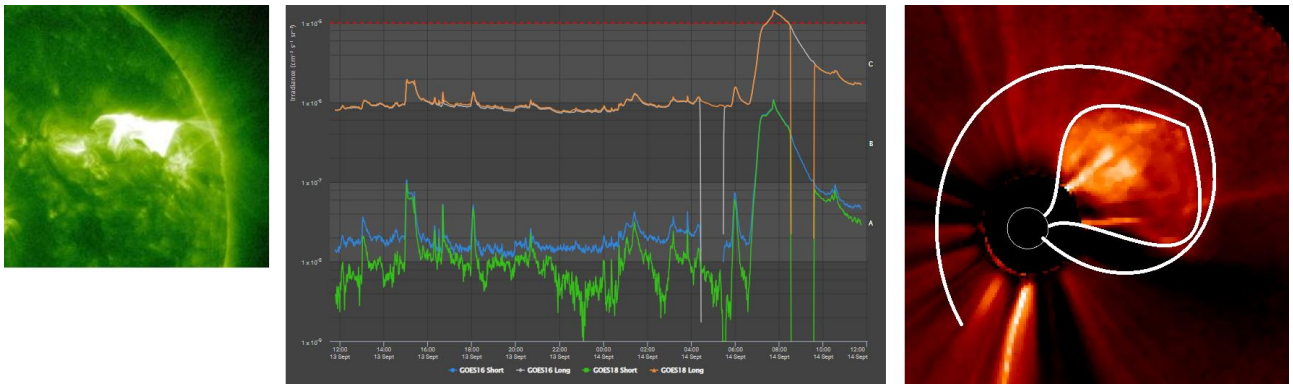

Figure 0: Left to right: AIA94 extreme UV image of peak M1.4 flare from a filament neighbouring AR3423; Associated GOES16 and 18 X-ray flare trace (including eclipse of GOES18); Resulting 14/0930UTC STEREO A COR2 coronagraph image. The main ejecta can be seen to be heading north and west of the Sun-Earth line, but there does appear to be a partial halo component (shown as the outer white outline). This CME has yet to be analysed.

The neighbouring sunspot remained the largest and most complex of up to nine on the facing side at present, with AR3423 an Eki/Beta-Gamma. Its leading and central portions showed an overall slight areal decline in the period, while there are signs that its large penumbral trailing group is bifurcating. The other main group that developed on the disc was AR3329 in the northeast, which showed notable proliferation of its intermediate spots, albeit with no related significant flare activity. The remaining other main bipolar regions showed more open centres and decay with time, with both AR3425 and AR3430 showing this tendency.

The CME tied to the aforementioned M1.4 filament eruption has not yet been analysed, however no other events of note were observed, and at the time of writing, no confirmed Earth-directed CMEs were observed during the past 24 hours.

Solar Wind / Geomagnetic Activity: Solar wind parameters, as measured by ACE and DSCOVR at L1, were perhaps indicative of a descent into a slow regime, but with a notable reversal starting

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around 14/0300UTC, likely a CIR ahead of what is likely to be coronal hole fast wind 44/+ (although the phi angle has yet to settle).

Solar wind speeds initially fell from Slightly Elevated levels near 425 into the upper-300s, before rising more sharply to an Elevated high near 500km/s through the UTC morning. The solar wind density was initially stable near its long-term average of single figures ppcc, but this rose to a peak in the low teens by mid-morning before moderating slightly before the period's end. The IMF showed a gradual rise from 6 to 10nT, falling back to earlier values in the final few hours. The north-south component, Bz was variable, with a maximum scope of -7 and +8nT, with much of the UTC evening spent in anti-aligned territory near -5nT. The phi angle was mainly positive (away from the Sun), but more variable to start and end the 24 hours.

The net effect of the above solar wind measures was for provisionally Quiet to Active geomagnetic activity, with Kp reaching '4o' in the 00-03UTC interval.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux has been at Background levels.

GOES16 high energy (greater than 2MeV) electron flux was at Normal Background levels. The associated 24-hour fluence was well below the Active threshold, with 1.35e6 integrated pfu observed at 14/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: There is a daily Chance of M-class flares, mainly from AR3423 in the northwest, and perhaps now AR3329 nearing centre-disc. AR3323 should leave the Earth-facing side over the coming UTC weekend, but the flare risk may be maintained by the return of Ex-AR3413 in the east, which may be the source for some large recent far-sided CMEs and, by inference, large flares.

Solar Wind / Geomagnetic Activity: Two CMEs that left the Sun on 11 September may give glancing blows at Earth between days one to three (14 to 16 September), however, any potential effects at Earth are expected to be small if they do arrive. There is also one unassessed candidate - the M1.4 filament CME noted above.

Coronal hole fast wind influence from CH44/+ is expected to be imminent, beginning day one (Thursday 14 September), with speeds increasing Elevated levels initially, then perhaps to Strong levels by later day two or day three (15 into 16 September) as CH47/- takes over. Speeds may then begin to slowly ease to round-out the current forecast period.

Initial Active (Kp4) intervals and a Slight Chance of G1/Minor Geomagnetic Storm (Kp5) intervals should gradually give way to a diminishing Slight Chance of similar G1s on subsequent days, with day four Quiet to Unsettled

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is expected to remain at Background levels, with a Slight Chance of an enhancement should any larger flares occur from AR3423 in particular.

High energy (greater than 2 MeV) electron flux is likely to be suppressed at Normal Background levels at GEO through much of the period, but perhaps with an eventual increase to diurnal High levels on day four (Sunday 17 September). Overall, the 24-hour fluence is Expected to remain below the Active threshold throughout the period, with reducing confidence later in the UTC weekend.

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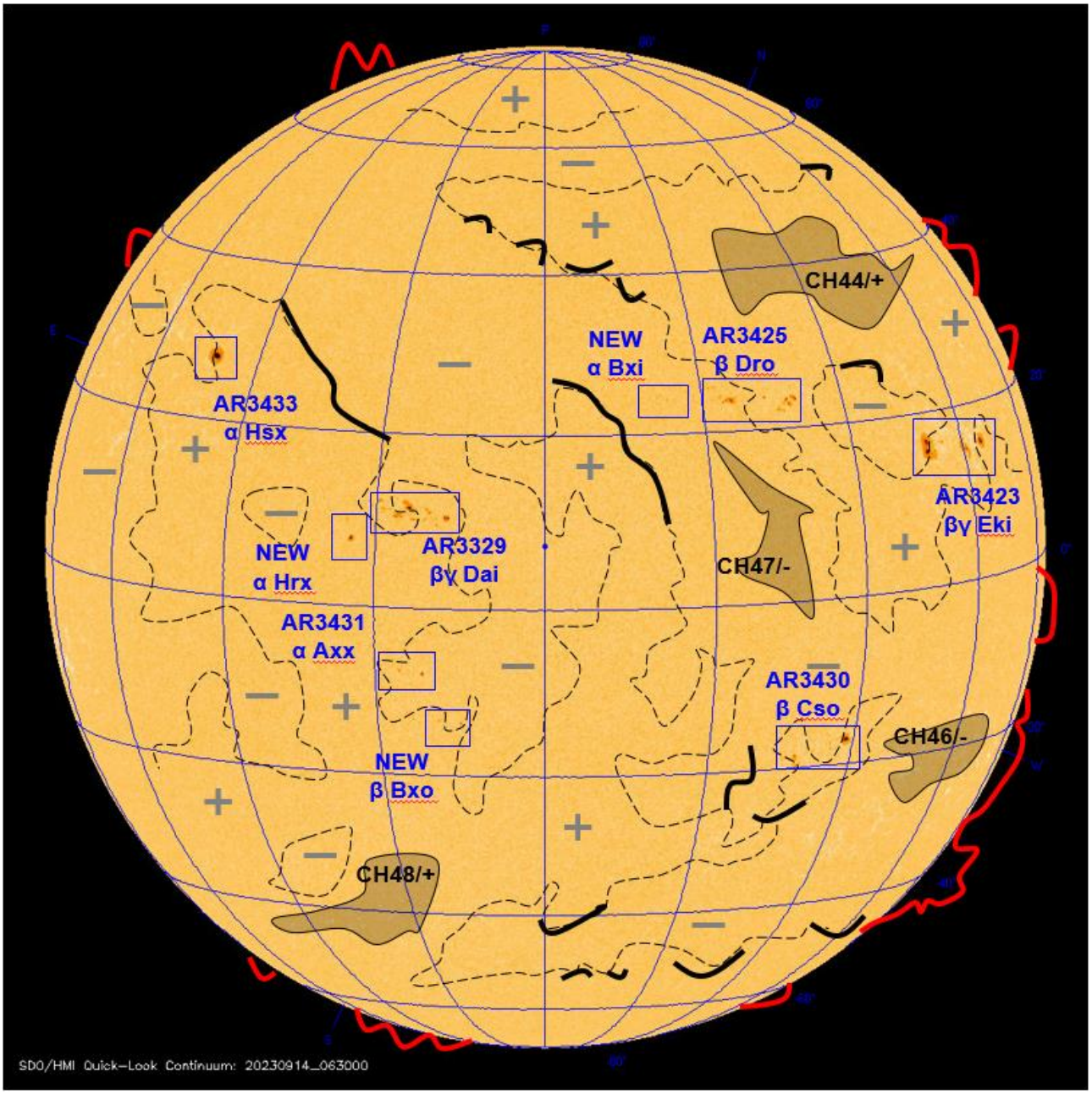
Figure 1. Solar Analysis Valid 14/0630UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There is the possibility for two glancing impacts from CMEs in the forecast. A third CME is awaiting imagery for analysis and does not yet feature in the figures.

The first confirmed CME resulted from an M1.3 and associated filament eruption from AR3429 around 11/0130UTC. This was a fairly large and well-defined in coronagraph imagery, but originated from an area in the far northeast quadrant. There is a slight chance of a glancing impact from this either late day one (14 September) or early day two. A second CME resulted from a filament eruption in the south-centre disc around 11/1400UTC. This gave a CME which appeared slow, largely southward-directed and relatively faint in imagery. Analysis has shown that this may give Earth a weak glancing blow possibly later on day two (Friday 15 September) or early day three. Overall, little effect on geomagnetic activity is expected from either of these CMEs - if they arrive at Earth.

Coronal hole fast wind enhancements are expected into the forecast period, and should predominate. Firstly - and most likely - these should arise from CH44/+ in the northwest disc, though the MOSWOC Enlil model output continues to signal CH46/- in the southwest as the dominant feature. The onset of the influence from either or both these features is expected to now be imminent, with a CIR already in course at L1, and with a subsequent increase in winds to Elevated levels (450-550km/s) now likely.

From day two (15 September) a connection to equatorial CH47/-, in the western hemisphere is then likely. This feature was perhaps the source of some Strong solar winds (around 600km/s) on the last solar rotation, with a chance that winds may reach these levels later day two and into day three (15 into 16 September) before slowly easing, though probably still at Elevated levels. Geomagnetic activity with this high-speed stream on the last rotation was muted (peaking at Kp3 - Unsettled), despite the Strong solar speeds observed. Negative polarity coronal holes are generally less geoeffective at this time of year, so similar Geomagnetic activity is probable again with this enhancement.

The above creates a somewhat complex and lower-than-average confidence forecast, with a variety of potential coronal hole and minor CME interactions. There is little assistance at present from Enlil modelling. G1/Minor Storm (Kp5) intervals are most likely on day one (14 September) with a diminishing, low or very low chance on subsequent days.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	20	10	10	5
Strong	G3	No	3	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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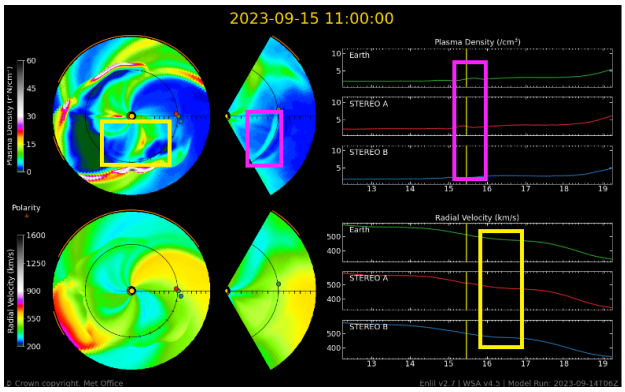
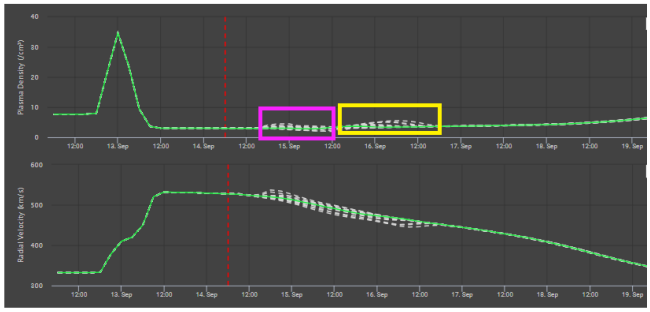
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
11/0357	Partial	M1.3 flare and filament eruption	AR3429	626km/s	14/1800+/-9h	Limited shock expected. Low confidence on arrival.
12/0209	Partial	Filament eruption	SE	450km/s	15/1800+/-9h	Limited shock expected. Low confidence on arrival.

Figure 2: Latest MOSWOC Enlil run, showing extreme glancing incidence from either of the two 11 September CMEs – one mainly trailing Earth on the ecliptic (yellow) and one mainly below (magenta).





Radio Blackouts - X-Ray Flares:

There is a daily Chance of M-class flares and a Slight Chance of isolated X-class.

The main regions to watch are thought to be AR3423 in the northwest, but now also perhaps the rapidly proliferating AR3329 that is now nearing centre-disc. Even though the disc has seen an M-class flare in the past 24 hours, this was due in large part to the presence of a filament near AR3423. So, while instability in the spot group very probably contributed to the flare, this was probably a one-shot event, and the Zurich class of AR3424 is probably an over-estimate of the risk from this region on the whole. Global probabilities of flares have therefore been revised downwards very slightly to better match the more general observation of there being very few flares of any size on the disc at present.

In terms of the forecast, AR3423 is expected to rotate off the visible disc through day three (Saturday 16 September), however, far-side sounding data suggests that a large region is expected to rotate over the eastern horizon on the same day to mitigate against any otherwise declining risk. This arriving region is expected to be the returning Ex-AR3413, which was responsible for numerous M-class flares when last on the visible disc. A number of large, far-sided CMEs can likely be attributed to the region in the past several days, suggesting it is still active and has survived its transit of the far side.

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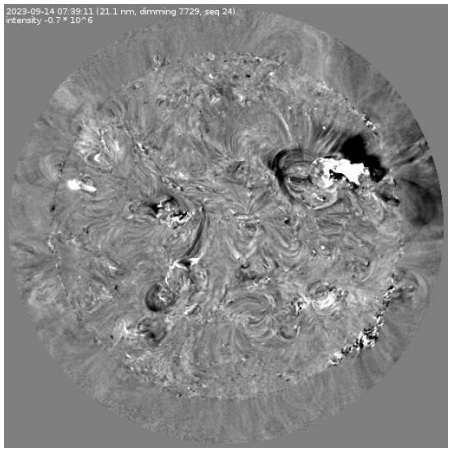
X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	50	50	50	50
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: SIDC ROB time-integrated AIA 211 dimming in the wake of the M1.4 flare from the northwest quadrant.



Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is expected to persist at Background levels. The M1.4 flare from the current UTC morning is now perhaps sufficiently long ago that there is now unlikely to be any additional risk of a proton enhancement in the near-Earth environment.

This means that there remains a daily Slight Chance of flux levels rising in response to any significant flaring, particularly as AR3423 and AR3425 continue to move across the western solar hemisphere.

Radiation Storms	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ S1	No	10	10	10	10
Very Active	≥ S3 *	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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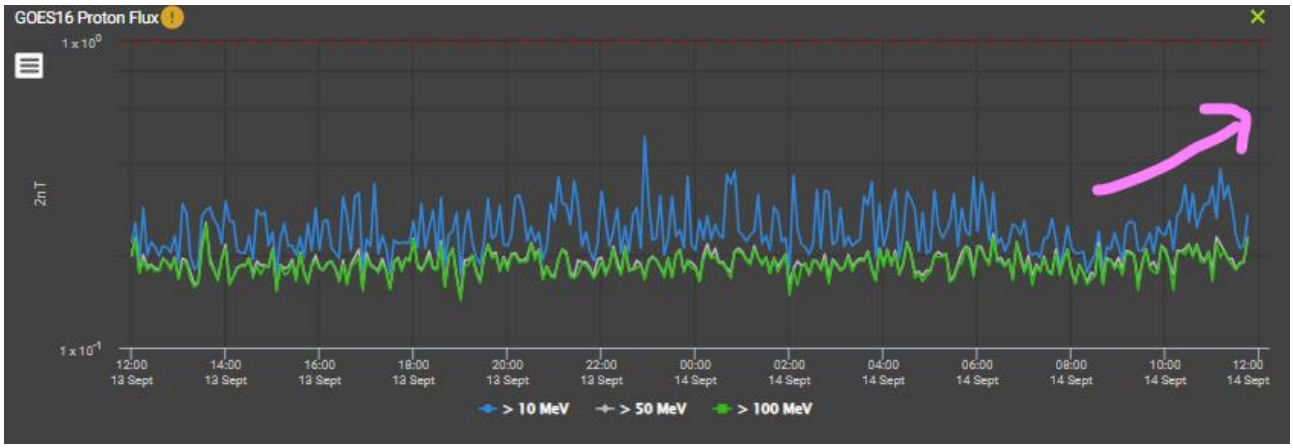
Figure 4: Latest GOES16 high energy proton flux for past 24 hours, showing perhaps a very slight reaction to the current UTC morning's M1.4. This response (if real) looks to be very damped and is not expected to challenge the S1 threshold.



High Energy Electrons Event (≥ 2MeV):

High energy (greater than 2 MeV) electron flux observed by GOES16 is expected to remain generally at Normal Background levels through much of the period. The rationale for this is the succession of fast winds should give a sustained period of elevated geomagnetic activity that will serve to compress the Van Allen belt inside GEO and lead to an apparent decline in populations. The chances of this remaining the case into day four (Sunday 17 September) are relatively lower as the fast wind(s) mature, and electron flux may then rise to High levels at diurnal peak.

The associated 24-hour fluence will most likely remain below the Active (1e8 integrated pfu) threshold for much of the period, however there is perhaps a Slight Chance by the end of the UTC weekend in a late recovery in fluence. MOSWOC REFM is considered to be giving good guidance in the near term, with any CME influence at a minimum and with current coronal holes likely to deliver a similar response to last pass, although the main period of interest is the 72 to 96-hour period, which falls outside REFM's range.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	10	20
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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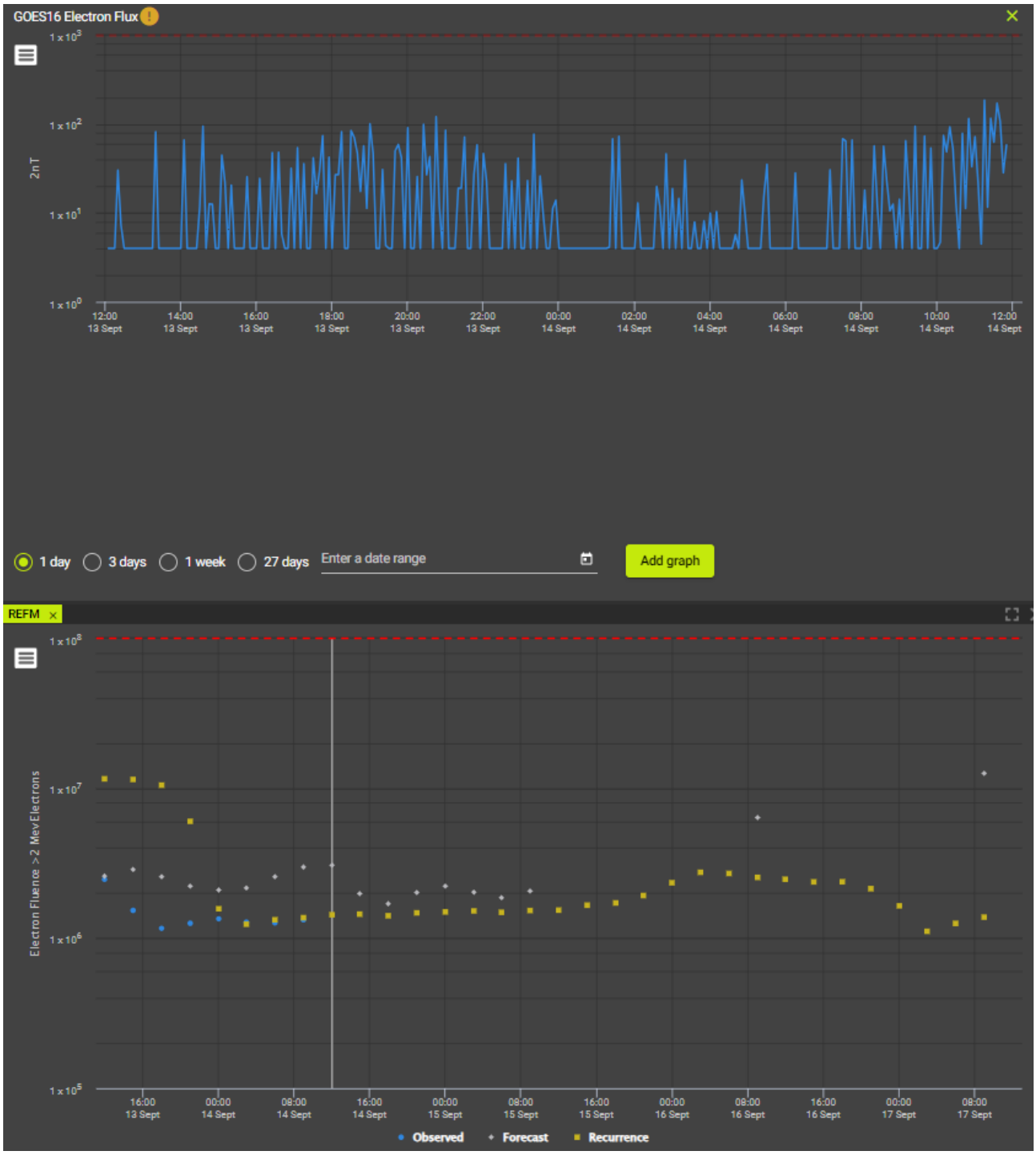
Figure 5: Past 24 hours in GOES16 high energy electrons, showing a Normal Background trace. MOSWOC REFM hints at a forecast rise in the coming three days, however it is not until the fourth day that any real response may be expected, so while accepted, REFM will become of increased interest in the coming 24 hours as its range covers the period in question.



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